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Differentiating retrospective from prospective memory delayed matching-to-sample versus delayed discrimination tasks.

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DIFFERENTIATING RETROSPECTIVE FROM PROSPECTIVE MEMORY: DELAYED MATCHING-TO-SAMPLE VERSUS DELAYED DISCRIMINATION TASKS

by

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To Harriett

Abstract

Rats were trained either on a successive delayed matching-to-sample task (DMTS) in which reinforcement was contingent upon lever pressing to a light or tone test stimulus (S_2) if it matched a prior sample stimulus (S_1), or on a delayed discrimination task (DD) in which reinforcement was contingent upon lever pressing to the test stimulus if the sample stimulus was a light for some rats or a tone for others. Rats in either task received asymmetrical reinforcement in one phase in which reinforcement occurred only for correct lever responses and symmetrical reinforcement in another phase in which reinforcement also occurred for correct omission of lever pressing. Increasing the delay between S_1 and S_2 reduced accuracy in discriminative responding in both tasks. Only in the DMTS task, however, was accuracy in matching to the visual S_1 poorer than to the auditory S_1 with increased S_1-S_2 delays. Symmetry of reinforcement only affected accuracy of responding in the DD task, with symmetrical reinforcement producing poorer discriminated responding than asymmetrical reinforcement with increased S_1-S_2 delays. These results were discussed in terms of Honig and Thompson's (1982) notions of retrospective and prospective processes in working memory.

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CHAPTER I

INTRODUCTION

Since the inception of experimental psychology, researchers have proposed models of memory that share a common dualism at their base. The models of James (1890), Broadbent (1958), and Atkinson and Shiffrin (1968) all postulate a basic distinction between primary or short-term memory, one that endures for a very brief period of time, and secondary or long-term memory, the knowledge of a prior event that is no longer represented in consciousness but has to be recollected into awareness. In human subjects, both short-term and long-term memory have been experimentally investigated, but in animal subjects research on short-term processes has predominated.

Hunter (1913) was probably the first memory researcher to work with animals. He introduced the following example as an illustration of short-term memory in animals.

> A cat watches for a mouse and sees it appear at an open hole. The mouse vanishes before the cat can react, yet the cat goes over to the hole. There can be no question here but that the determining stimulus is absent at the moment of response, provided. possible olfactory stimuli be neglected (Hunter, 1913, p. 1).

In his empirical research, Hunter (1913) employed a special chamber containing three small boxes. On a given trial, an animal subject was placed at the entrance of the chamber. A light would go on in any one of the three exit boxes. After five seconds, the subject was released into the chamber. If the animal went directly to the lit box, he would obtain food. A trip to the unlit box meant no reward on that trial.

After the animal was trained to a criterion performance level, delays

were introduced. At first, the light was turned off just as the animal reached the lit box. In the second delay stage, the light was shut off when the animal was half-way to the box. In the third stage, the light was turned off just as the experimenter released the animal into the chamber. Finally, the animal was detained one or more seconds after the light was out before being released. A similar procedure was carried out with young children. Hunter found that rats did very poorly with delays beyond 25 seconds, dogs and raccoons showed severe memory decrements with delays greater than five minutes, and children could tolerate delays of up to 25 minutes. Hunter also found that rats and dogs relied on body orientation for successful performance. Both species, when put in the entrance waiting box, would orient their entire bodies toward the light immediately and maintain that orientation during the delay. When released, they would merely move in the direction of their body orientations toward the appropriate box. Raccoons and children, however, did not rely on body orientation to perform the task. Hunter postulated that some "intraorganic factor" was necessary to account for the successful performance of these subjects.

Following Hunter, other researchers (e.g., Cowles & Nissen, 1937; Finan, 1942; Harlow, Uehling & Maslow, 1932; Maier, 1929; Schiller, 1949; Tinklepaugh, 1928) employed variations on his delayed response task, generally using monkeys or rats as subjects. As a group, these studies revealed that in delayed reaction procedures, successful performance with very large delays was associated with fewer trials per day, with the reverse being true in studies involving short delays (see Weiskrantz, 1968).

Whereas Hunter's (1913) study and many of those based on it focused

on the short-term retention of location, Weinstein (1941) reports that Kohts (1923), a Russian psychologist, developed the delayed matching-to-sample (DMTS) paradigm for color and form. She showed a sample object to a chimpanzee, Ioni, who had to select its duplicate from among a group of diverse choice objects for a food reward. After about three years of training, the chimp succeeded in matching a large variety of colors and color combinations, an extensive assortment of figures, and even several letters of the alphabet. Ioni's accuracy fell to chance levels, however, when delays of more than 15 seconds occurred between presentation of the sample and choice objects. Weinstein (1941) conducted a similar experiment with rhesus monkeys and found that all subjects achieved approximately 80% accuracy in the last 25 trials at the 5, 10, and 15 second delay intervals. These results thus replicated Kohts' earlier findings.

Blough (1957, 1959) conducted experiments to investigate delayed matching-to-sample in pigeons' working memory. In his 1959 study, he trained four pigeons to match-to-sample; the two samples were a steady and a flickering light. The birds' matching performance differed markedly at delays of 5 and 10 seconds. Two birds performed well with these delays, and two did not. Blough noted that both successful birds engaged in sample-specific behaviors during the retention interval. For example, one bird always backed away from the flickering key and waved its head slowly back and forth; whereas, during the steady light, it pecked rapidly at the top of the sample stimulus aperture. When a bird made the sample-specific response characteristic of the wrong sample during the delay interval, it responded incorrectly to the test stimuli. Additionally, when, because of a change in the apparatus, the same sample-specific response occurred to each sample stimulus, correct

performance at long delays disappeared in the previously successful birds. The strong association between specific test responses and sample-specific behavior suggested that the animals were utilizing such behavior as a mediator to represent the sample during the retention interval.

Blough's (1957, 1959) studies marked the beginning of much interest in DMTS as a means of investigating short-term memory in the pigeon (e.g., Roberts & Grant, 1976), monkey (e.g., D'Amato, 1973), dolphin (e.g., Herman & Gordon, 1974), and goldfish (Steinert, Fallon & Wallace, 1976). In addition, other paradigms, variations on the Kohts (1923) method, have been developed and utilized. These methods all involve: 1) an initial stimulus or stimuli; 2) a retention interval; and 3) a test stimulus or stimuli to which the animal is to respond. In the case of successive delayed matching-to-sample (Konarski, 1959), a single stimulus is presented on the initial trial, and a single stimulus is presented on the retention trial. If the two stimuli are identical, the animal is rewarded for making a response; if they are different, the animal is not rewarded for making a response. Many subsequent studies have utilized this procedure (e.g., Chorazyna & Stepien, 1961; Cohen, Escott & Ricciardi, 1984; D'Amato & Worsham, 1974).

In delayed symbolic matching (DSM) (Honig & Thompson, 1982), the subject is presented with several test stimuli after the retention interval, from which he is to respond to the one that is associated with the initial stimulus. Whereas in the Kohts' (1923) DMTS procedure, the correct test stimulus is physically identical to the initial stimulus; in DSM, the correct test stimulus is arbitrarily associated with the initial stimulus and need not physically resemble the initial stimulus. For example, a test stimulus of two vertical lines may be linked in the

experiment with a light as the initial stimulus.

If only one test stimulus is presented after the memory interval, this turns symbolic matching into a successive delayed symbolic discrimination (DSD) (e.g., Nelson & Wasserman, 1978). In this paradigm, the trial outcome is determined conjointly by the initial stimulus and the test stimulus. If trial outcome is solely dependent on the initial stimulus, with the test stimulus being irrelevant, the task becomes a delayed discrimination (DD). Another complex discrimination matching task employs several initial stimuli presented successively as samples, followed by a single test stimulus which may either come from the initial set of sample stimuli or be a novel stimulus. In this serial probe recognition (SPR) task, the subject must respond differentially to the test stimulus depending on whether or not it is one of the initial samples (MacPhail, 1980).

Although researchers of animal memory have used these procedures, until recently they have not interpreted their findings within any theoretical framework but only in terms of the specific paradigmatic constraints used. In an attempt to make sense of the somewhat confusing and seemingly unrelated results that have collectively accrued with these various procedures, Honig and Thompson (1982) postulated two types of processes that subjects may be employing in these various short-term memory tasks: Retrospective and prospective memory. They note that memory in delayed matching tasks has been traditionally conceived of as being retrospective; that is, the animal maintains a representation of the initial stimulus during the retention interval. This representation could take the form of a decaying trace (Roberts & Grant, 1976), or differential mediating behavior (e.g., Blough, 1959). If such a

representation is maintained, it provides the information necessary for the subject to make a correct response decision at the end of the memory interval. A recognition process may also be involved in which the subject scans its recent past to determine which stimulus occurred most recently.

In addition to retrospective processes, Honig and Thompson (1982) assert that animal working memory can be prospective or anticipatory. If the animal can represent the probable trial outcome at the time of the initial stimulus, it may make an appropriate response decision at that time and maintain the decision during the memory interval, as well as or rather than maintain some representation of the initial stimulus. The main distinction, then, between retrospective and prospective memory relates to the content of memory. In retrospective memory, the subject maintains a representation of the initial stimulus; with prospective memory, the subject maintains a representation of the appropriate response decision and outcome during the retention interval. Remembering up to the point of the response decision is retrospective, with stimulus representation. After the decision has been made, memory is prospective, with outcome and response representation.

Honig and Thompson (1982) note that for all the procedures previously mentioned except the SPR task, the amount of information carried by the initial stimulus is the same. Consequently, it is reasonable to suppose that memory performance based on retrospective processing should not differ across these procedures. Conversely, the amount of stimulus information that would have to be carried in prospective memory does differ among these tasks. In the delayed discrimination task, the instruction is simple; e.g., "respond" or "don't respond". In the other paradigms, however, the prospective function would also have to carry

stimulus content, such as "respond if light, don't respond if tone". This more complex instructional set may be less easy to rehearse or remember so that the subject may simply opt for a retrospective process.

From the preceding discussion, it is evident that both processes can lead to the correct behavioral outcome for the subject. A major issue, then, is to determine which process the subject is employing in a given task. Honig and Wasserman (1981), conducted two experiments with pigeons to distinguish between the retrospection of the initial stimulus and the anticipation of the trial outcome. Subjects were successively presented with a sample red or green stimulus displayed on the response key and then, following a retention interval, a line orientation as the test stimulus. In the simple discrimination (DD), the sample provided the necessary information regarding the subsequent trial outcome (e.g., if S_1 = red, press for reward). In the delayed symbolic discrimination (DSD), the sample and the test stimuli conjointly provided this information (e.g., if S_1 = red and S_2 = vertical lines, press for reward). Results showed that not only was the simple discrimination learned more quickly but performance on this task was less disrupted over a set of delay intervals than for the symbolic discrimination. If subjects had employed retrospective memory in both tasks, there should have been no difference in the performance between these discrimination tasks. The superior performance displayed on the delayed discrimination task suggests two alternative explanations. The first is a purely prospective account. At the time of the sample stimulus, the pigeon may encode the appropriate response decision and remember it. In the delayed simple discrimination, the bird's decision is merely to respond or not to respond to either test stimulus when it appears. In the delayed symbolic discrimination, the

decision has to include a stimulus component as well (e.g., respond if the test stimuli is vertical, do not respond if it is horizontal). Such a stimulus-contingent rule in the DSM task may be harder to acquire initially and remember over a longer memory interval than the rule in the DD task.

The second explanation is that prospective memory was used in the delayed discrimination task, while retrospection was employed in the delayed symbolic discrimination; that is, the learning and memory functions for the two tasks were different because a different process was employed in each task. Though no definite conclusion was reached as to which of the two accounts is correct, other studies have been conducted which further evaluate the type of memory processes operating in different paradigms. The results of one study (Wallace, Steinert, Scobie & Spear, 1980) suggest that rats may rely primarily on retrospective memory in delayed symbolic tasks and delayed matching-to-sample tasks. In their first experiment, on delayed symbolic matching, the subject produced either a visual or auditory initial stimulus for four seconds by pressing a lever on the rear wall of the test chamber. The visual stimulus consisted of diffuse chamber illumination; the auditory stimulus was white noise projected from a speaker in the ceiling. After the memory interval of 0, 2, or 4 seconds, one of two white light test stimuli, located above response levers in the chamber's front wall was turned on. Three rats had to press the lit lever following the auditory initial stimulus and the nonlit lever following the visual initial stimulus. For the remaining two subjects, the response rules were reversed. Assuming that the rats remembered the response rules prospectively, similar overall memory functions for the visual and auditory initial stimuli should have been found. However, at the 2 and 4 second delays, there was a

considerable drop in response accuracy following the visual initial stimilus, although performance levels following the auditory initial stimulus did not change.

As can be seen, the rats' memory functions in the delayed symbolic matching task were determined by differential forgetting of the two initial stimuli, not by response rules. This finding was supported by the results of Wallace et al's (1980) second experiment with a successive delayed matching (DMTS) paradigm. In this task, pressing a single lever was rewarded if the initial stimulus and the test stimulus were the same (i.e., light-light, tone-tone) and not rewarded if they were in different modalities (i.e., light-tone, tone-light). Results revealed that at the 5 second retention interval, rate of forgetting all trials with a visual initial stimulus was significantly greater than for all trials with an auditory initial stimulus, regardless of test stimulus modality.

Consequently, in both DSM and DMTS tasks, the rats' memory performance was related to the modality of the initial stimulus. This finding makes sense if we assume that 1) the rats were remembering retrospectively in the tasks, and 2) the rats' memory is poorer for visual than for auditory stimuli.

In a more recent study (Cohen, Escott & Ricciardi, 1984) rats were employed as subjects in a successive delayed matching-to-sample task. The experiment was similar to the Wallace et al. (1980) investigation except for the addition of symmetrical versus asymmetrical reward conditions. Cohen and his associates noted that the problem with the standard successive DMTS procedure is that the payoff matrix is asymmetrical in nature. The animal is rewarded for correct presses but has nothing to lose for making incorrect responses. This creates a bias

to press in the animal which may result in underestimating the animal's retention of the initial stimulus. For this reason, Cohen et al. included a symmetrical reward condition, in which the animal received reward for pressing on matching trials (L-L, T-T) and reward for not pressing on nonmatching (L-T, T-L) trials.

Cohen et al. (1984) found that accuracy for matching to the initial tone stimulus appeared to be superior in symmetrically reinforced than asymmetrically reinforced DMTS with increased S_1-S_2 delays. This corroborated similar findings in monkeys (D'Amato & Worhsam, 1974), and pigeons (White, 1974). Cohen et al. also replicated Wallace et al's (1980) finding that rats retain retrospectively visual events more poorly than auditory events. These findings contrast with the data for dolphins, which seem to indicate prospective mediation in the DMTS, DSM, and DSD paradigms (Herman & Thompson, 1982). However, as Honig and Thompson (1982) point out, it is not yet clear whether the different memory strategies used by these animals were the consequences of paradigmatic constraints, or reflect inherent species predispositions. Moreover, retrospective-prospective interpretation of the data is merely speculative and the distinction itself is based on a post-hoc analysis of the findings of such studies. From the existing data, it is not possible to clearly specify the conditions under which retrospective and prospective processes are likely to be active.

Statement of the Problem

Better performance in delayed discrimination (DD) than delayed matching-to-sample (DMTS) may indicate that easier to retain prospective rules are used in the former but more difficult to retain retrospective rules are employed in the latter (Honig and Thompson, 1982). Such

differences in performance, however, might merely reflect the use of a more complex and thus more difficult to retain prospective rule over longer retention intervals in DMTS tasks. This explanation, however, can not account for better delayed auditory than visual matching-to-sample in rats (Cohen et al., 1984; Wallace et al., 1980). These modality-specific effects further point to the operation of retrospective processing in DMTS. Perhaps a better way to differentiate DMTS from DD tasks is to determine if S_1 modality affects increased delayed responding differently in each task. If prospective processes predominate during DD, subjects should not have to remember the physical nature of the initial stimulus but only to retain the instructional set as to whether to respond for reinforcement. Consequently, the modality of S_1 should primarily affect delayed performance for DMTS rather than for DD tasks.

A second factor shown to influence DMTS behaviour is the symmetry of reinforcement. Cohen et al. (1984) found that a bias to respond with increased retention intervals was greater in asymmetrically than symmetrically reinforced DMTS especially when S_1 was a tone. The result of such differences was that accuracy of matching was better for the tone S_1 under symmetrical reinforcement. This factor might yield important differences between DD and DMTS tasks based upon the hypothetical uses of different mnemonic processes. Although symmetrical reinforcement might also reduce a bias to respond under less certain conditions in a DD task, it should also result in a more complex prospective rule than asymmetrical reinforcement. In an asymmetrically reinforced DD, the animal has to retain an expectancy for a reinforced response based on S_1. In the symmetrically reinforced DD, S_1 does not provide information about whether or not reinforcement will be available, but rather what type of behaviours

will be reinforced. This latter rule is more complex and should be harder to retain. Therefore, while symmetrical reinforcement may improve delayed matching-to-sample behaviour, it may actually disrupt delayed discriminative responding.

Design

The present research was designed to investigate the two hypotheses discussed in the preceding paragraphs concerning the effects of S_1 modality and symmetry of reinforcement on behaviour in DMTS and DD tasks. Two groups of rats were trained in a discrimination consisting of sequentially presented lights and tones arranged into four possible pairs: light-light, tone-tone, light-tone, tone-light. A retractable lever occurred with the onset of the second stimulus. During initial training the first and second stimuli were separated by 5, 10, and 20 second retention intervals. One group was trained and tested in the successive DMTS under asymmetrical reinforcement in one phase and symmetrical reinforcement in the other. For asymmetrical reinforcement, a liquid reward could be obtained only for pressing to the second stimulus if it matched the first; that is, light-light, tone-tone. In the symmetrically reinforced situation, reinforcement occurred for both correct presses when S_2 matched S_1 and for correct omissions of pressing to S_2 when it differed from S_1; that is, light-tone, tone-light.

The other group acquired a delayed discrimination in which the modality of S_1 alone determined the contingency for reinforcement. Each subject learned in separate phases that a light S_1 and a tone S_1 signalled that reinforcement could be obtained for lever pressing to any S_2. Within each S_1 discrimination, each animal acquired an asymmetrical and a symmetrical form of the DD task. In the latter, when a light (tone) S_1

signalled reinforcement for a press to S_2, then a tone (light) S_1 signalled reinforcement for not pressing to S_2. Testing for maintenance of performance over 5, 10, and 20 second retention intervals occurred following acquisition of each discrimination task.

CHAPTER II

METHOD

Subjects

Fourteen male albino (Wistar) rats from our breeding colony, aged 75-95d, initially served as subjects. Two of these animals had served as subjects in an operant discrimination with both stimuli as components of a compound S+. Two animals from the naive group were discarded from this experiment for failing to either initially acquire or reacquire their experimental task following retention testing. Of the final twelve rats, six completed the DMTS task, and six completed the DD task.

All animals were individually housed with food constantly available. They received 15 min. free access to water approximately 30 min. after each daily experimental session. Animals were on a 12h. dark/light cycle and were run during the dark cycle.

Apparatus

Four standard (BRS/LVE) small animal operant chambers, each equipped with a retractable lever and a 0.05 ml water dipper on one wall and five 24 watt lamps and a Mallory Sonalert tone generator in the ceiling, were utilized. Each chamber was housed in a standard (BRS/LVE) light and sound attenuating isolation chamber whose ventilation fan produced constant 55dB masking noise.

Two 2.5 s. stimulus events were employed: a 2.8 kHz 75dB tone from the Mallory Sonalert generator, and onset of the ceiling lights. The operant chamber remained dark during intertrial and retention intervals. An external speaker in the running room emitted 62dB white noise to

further mask sounds from the control room or corridor. Standard electromechanical programming and recording equipment were located in an adjacent room.

Procedure

Preliminary training. After three days of handling and maintenance on water deprivation schedules, the rats were shaped by approximation training to press an extended lever for 0.05 ml droplets of sweetened water (0.10% Sodium Cyclamate, wt/vol) in the illuminated chamber. Training continued until each animal could make 200 unassisted presses. A second session followed in the unlit chamber in which the lever was extended. The chamber remained darkened throughout the rest of this phase. Over the next seven sessions, animals were presented with the retractable lever every 30 s. for 100 trials. A press on the lever yielded reinforcement and retracted the lever. Time available to press decreased from 15 to 5 s. over those sessions.

DMTS acquisition and testing. The DMTS task consisted of sequential pairs of 2.5 s. light and tone stimuli in four possible orders: light-light, tone-tone, light-tone, tone-light. The two stimuli were separated by a 1 s. interval during acquisition sessions and between test blocks. Onset of S_2 was accompanied by a lever that remained out for a maximum of 5 s. Inter trial intervals from the onset of S_2 to the onset of the next S_1 were kept constant at 24 sec. during both training and testing sessions. The four different sequential pairs of stimuli appeared equally in each session in a semi-random order so that the same S_1 never occurred more than twice, and matching or nonmatching pairs never more than three times in a row.

Of the six rats trained and tested on the successive DMTS task,

three received the asymmetrically followed by the symmetrically reinforced form. The other three rats had the order of symmetry of reinforcement reversed. In either form of this task, reinforcement was given for pressing the lever to S_2 when it was the same as S_1 (light-light and tone-tone pairs). In the symmetrically reinforced form, reinforcement was also obtained for withholding a response to S_2 when it differed from S_1 (light-tone and tone-light pairs). Consequently reinforcement was available only for half the stimulus pairs in any session in the asymmetrically reinforced DMTS but could be obtained for all stimulus pairs in the symmetrically reinforced DMTS. An animal was considered to have acquired the DMTS discrimination when it correctly responded on 75% of its presses per session on two consecutive sessions and these correct presses accounted for at least 60% of the possible reinforcements that could be obtained through lever pressing on each session (30 out of 50 presses). Animals were allowed up to 120 sessions to reach this criterion before being removed from the experiment. Originally eight rats were trained in the DMTS tasks but two had to be removed for failing to initially acquire the discrimination.

After reaching criterion in either form of the DMTS, an animal received testing for S_1 retention. First it was given two sessions with 5 sec. S_1-S_2 intervals followed by training sessions with 1 sec. S_1-S_2 intervals until it regained the same criterion of performance achieved during initial training. A second block of two testing sessions with 10 sec. retention intervals was then given followed by training sessions to acquisition criterion. A final block of two testing sessions with 20 sec. retention intervals followed by training to criterion with the 1 sec. retention intervals followed. This procedure was repeated with

the other form of reinforcement symmetry. The criterion performance that preceded each retention test block served as baseline performance for that retention test. When an animal had finished one form of the DMTS task it received a minimum of four training sessions before any testing for S_1 retention began. Providing extra training with the new conditions for reinforcement even if criterion levels had been reached on the initial two sessions was considered necessary to acquaint the subjects with the shift in those conditions.

DD acquisition and testing. The same sequential pairs of stimuli, inter-stimuli and inter-trial intervals as used in the DMTS task were employed for the delayed discrimination tasks. The same pattern of initial acquisition to 75% criterion level followed by alternating testing and training blocks of sessions described in the preceding section was also used. The only major difference was the contingency for reinforcement in these discriminations. In the light discrimination, reinforcement in the asymmetrically reinforced form was given only for pressing to S_2 when S_1 was a light stimulus (light-light and light-tone pairs). In the symmetrically reinforced form of this discrimination, however, reinforcement was also received for withholding a response to S_2 when S_1 was a tone (tone-tone and tone-light pairs). For the tone discrimination, lever pressing to S_2 when S_1 was a tone was reinforced in both forms of this task but withholding a response to S_2 when S_1 was a light (light-light and light-tone pairs) was reinforced in the symmetrically reinforced forms.

Half the animals in the DD group received training and testing on both forms of the light discrimination followed by training and testing on the tone discriminations. When the modality of the S_1 stimulus signalling reinforced pressing was switched, we tried to keep the

symmetry of reinforcement constant to prevent further disruption of acquisition of the new task. Of the three animals that initially acquired the light discrimination, two received symmetrically and then asymmetrically reinforced light discriminations followed by tone discriminations in the opposite order of reinforcement symmetry. One animal was trained and tested first on the asymmetrically reinforced light discrimination then on the symmetrically reinforced light discrimination followed by the tone discriminations in the opposite order of reinforcement symmetry. Of the three rats that initially acquired the tone discrimination only the one that had first learned the symmetrically reinforced form went through this ABBA sequence of changes in symmetry of reinforcement. The other two rats that had first been trained and tested on the asymmetrically then the symmetrically reinforced forms of the tone discrimination failed to respond to the symmetrically reinforced light discrimination on the first seven sessions. Therefore we retrained and tested these rats on the asymmetrically reinforced light discrimination and then on the symmetrically reinforced form in order to collect data.

Data analysis. Before receiving a block of 200 test trials a rat had to respond to criterion on a block of 200 regular training trials (2 sessions). Data from immediately preceding training trials provided baseline performance for comparison to that on the 200 retention test trials. Each retention and baseline block of trials contained 100 matching and 100 nonmatching stimulus pairs, half beginning with the visual S_1 and half with the auditory S_1. Proportion of reinforced and nonreinforced bar presses for each S_1 (out of 50 possible responses in DMTS and 100 possible responses in DD) was recorded for each animal. Correct responding

to S_1 was measured by an estimate of signal sensitivity, $P(\bar{A})$, calculated from both proportion of reinforced and nonreinforced responses, as derived by McNicol (1972). $P(\bar{A})$ is an estimate of P(A), the proportion of area under a receiver operating curve (ROC) defined by several pairs of correct (hits) and incorrect (false alarms) responses. As P(A) makes no assumptions about the distribution of sensory effects of the signal trace or noise upon the subject, it can be determined graphically. P(A) can range from .50, responding to S_1 at chance, to 1.00, perfect responding to S_1. $P(\bar{A})$ is determined from only one pair of proportion of reinforced (hits) and non-reinforced presses (false alarms). Two possible ROC curves can be determined from a single pair of hit and false alarm proportions: A boundary determined by a line through the actual data point and a point where the proportion of hits and false alarms are both 0, and a boundary generated by a line through the data point and a point where proportion of hits and false alarms both equal 1.00. $P(\bar{A})$ is the average of the areas lying under both lines. Instead of calculating $P(\bar{A})$ graphically, one can algebraically compute the area under each line and then calculate the average by the following formula:

$$0.5\ [4\ \underline{x}\ \underline{y} - 3\ \underline{y} - \underline{y}^2 - \underline{x}^2 + \underline{x} / 2\underline{y}\ (\underline{x}-1)]$$

where $\underline{y}$ = proportion of reinforced responses or hits and $\underline{x}$ = proportion of nonreinforced responses or false alarms. McNicol (1972) presents a table of $P(\bar{A})$ entries from pairs of proportion of hits and false alarms based on this formula. $P(\bar{A})$ should also range from .50, chance responding (equal proportion of hits and false alarms) to 1.00, perfect responding.

As noted by Cohen et al. (1984), the $P(\bar{A})$ index is superior to the discrimination ratio (DR) of number of correct responses over total number

of responses. DR may overestimate retention by accounting only for incorrect responding; $P(\bar{A})$ takes into account both incorrect responses and incorrect omissions. For example, if an animal makes no nonreinforced responses but only responds correctly 20 out of 50 possible times, DR would indicate a perfect score of 1.00, but $P(\bar{A})$ would more accurately reflect a somewhat poorer score of .84.

CHAPTER III

RESULTS

Proportion of reinforced (hits) and nonreinforced (false alarms) presses were calculated for each animal at each baseline and test block and transformed into $P(\overline{A})$ scores. These proportions were further transformed into arcsin scores as suggested by Winer (1971) in order to normalize the data and reduce their heterogeneity of variance. A five-way analysis of variance [Task (DMTS, DD) x S_1 stimulus (light, tone) x Reinforcement Symmetry (asymmetrical, symmetrical) x Blocks (baseline, delay sessions) x Retention Interval (5, 10, 20 sec.)], in which the last four factors were repeated, was conducted on each dependent variable. Individual comparisons were carried out by Newman-Keuls tests, as suggested by Ferguson (1981).

Proportion of reinforced (hits) and nonreinforced presses (false alarms). Figure 1 shows the proportion of hits and false alarms at each baseline (1 sec. RI) and test block (5, 10, and 20 sec RIs) for each S_1 to which presses produced reinforcement. The nature of each task determined which presses to which pairs of stimuli counted as hits and false alarms to each S_1. In the DMTS tasks, hits to the visual and auditory S_1 were presses made to L-L and T-T pairs respectively. False alarms to the visual and auditory S_1 were presses made to the L-T and T-L pairs respectively. In the DD task, hits to the visual S_1 were presses to the L-L and L-T pairs; hits to the auditory S_1 were presses to the T-T and T-L pairs. False alarms, however, were nonreinforced presses to the T-T and T-L pairs when pressing to the visual S_1 produced reinforcement, and nonreinforced presses to the L-L and L-T pairs when pressing to the auditory S_1 produced reinforcement. Thus hits

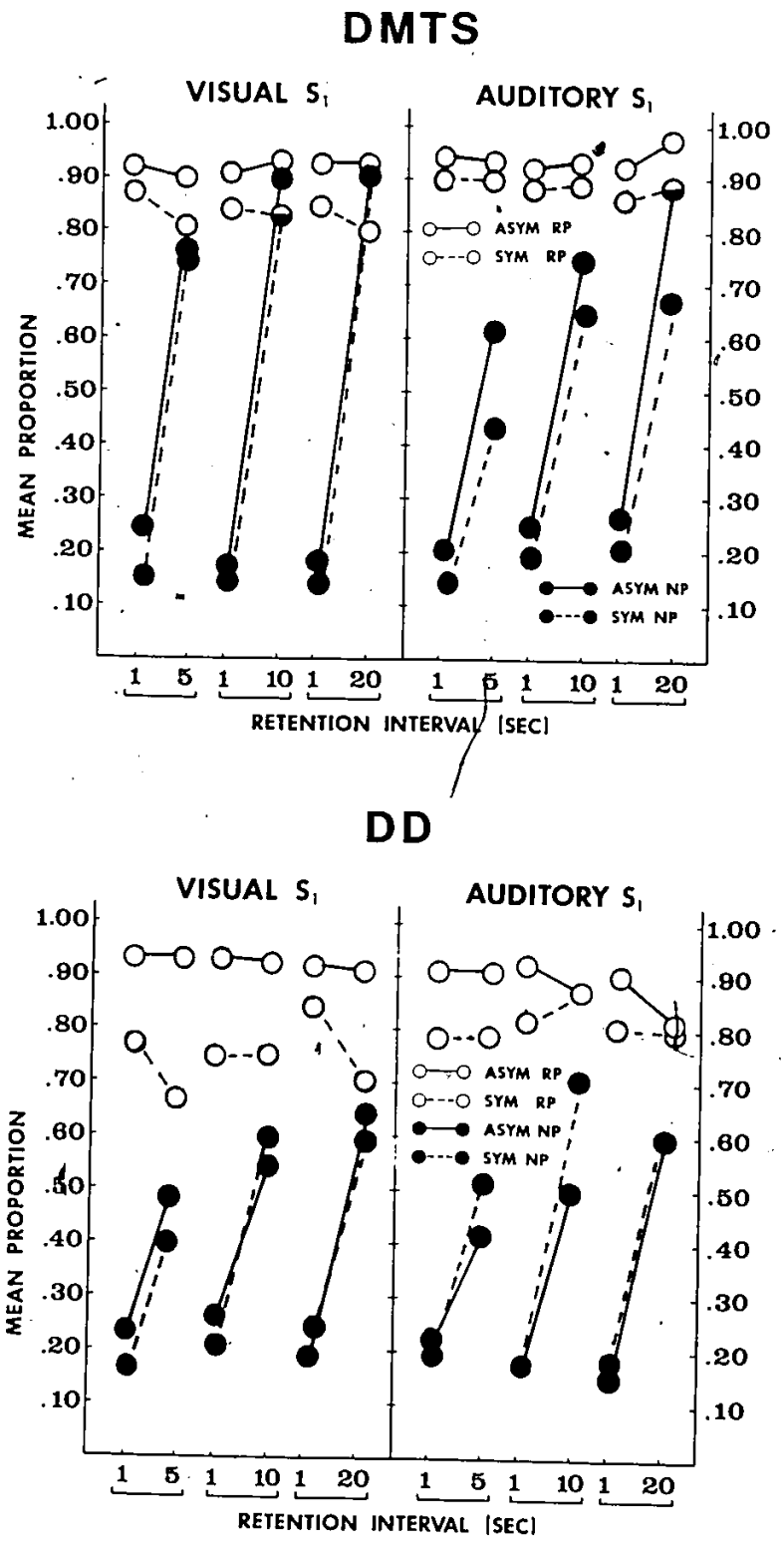
DMTS
VISUAL S1
AUDITORY S1
MEAN PROPORTION
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
ASYM RP
SYM RP
ASYM NP
SYM NP
1 5 1 10 1 20
RETENTION INTERVAL (SEC)
DD
VISUAL S1
AUDITORY S1
MEAN PROPORTION
ASYM RP
SYM RP
ASYM NP
SYM NP
1 5 1 10 1 20
RETENTION INTERVAL (SEC)

FIGURE 1

in both DMTS and DD tasks reflected reinforced pressing to the visual and auditory S_1 as labeled. False alarms reflected responding as if the labeled S_1 was absent in the DMTS task, but as if the labeled S_1 was present in the DD task.

Tables 1 and 2 present the analyses of variance and individual comparisons for hits and false alarms based on arc sin transformations.

Hits. As seen in Figure 1 and supported by a significant effect for Reinforcement Symmetry [F (1,10) = 43.36, $p < .001$], animals made more reinforced presses in the asymmetrically than symmetrically reinforced form of either task. A significant interaction between Task, Reinforcement Symmetry, and Retention Interval [F (2,20) = 5.10, $p < .05$] was due to more hits made by animals in the symmetrically reinforced DMTS than in the symmetrically reinforced DD task ($p < .05$) at the 5 sec. RI (pooled over blocks) (see Table 1a).

S_1 modality interacted with reinforcement symmetry to affect declines in hits. Only hits to the visual S_1 in the symmetrically reinforced tasks appeared to decline from baseline levels. A significant interaction between S_1 modality, Reinforcement Symmetry, and Blocks [F (1,10) = 6.74, $p < .05$] and individual comparisons ($p < .05$, see Table 1b) supported this observation.

False alarms. Inspection of Figure 1 reveals that increased RIs resulted in greater increases in false alarms from baseline levels and that this effect was greater for animals trained in the DMTS than DD tasks. Also evident from this figure was the fact that more false alarms were made to the visual S_1 than to the auditory S_1 only in the DMTS task. Reinforcement symmetry also affected increases in false alarms only in the DMTS task in which more false alarms were made in the asymmetrically than symmetrically reinforced form of this task to the auditory S_1. These

Table 1

Summary of Analysis of Variance of Hits for Task, Stimulus, Reinforcement Symmetry, Retention Interval, and Blocks

Source of Variation	SS	df	MS	F
Between Ss	11.307	11		
Task (T)	1.904	1	1.904	2.03
Error	9.403	10	.940	
Within Ss	24.256	276		
Stimulus (S)	.406	1	.406	2.98
S x T	.268	1	.268	1.96
Error	1.366	10	.137	
Reinforcement (R)	7.271	1	7.271	43.36***
R x T	.587	1	.587	3.50
Error	1.677	10	.168	
S x R	.304	1	.304	9.76*
S x R x T	.114	1	.114	3.64
Error	.312	10	.031	
Retention Interval (RI)	.011	2	.005	.07
RI x T	.026	2	.013	.17
Error	1.571	20	.079	
S x RI	.034	2	.017	.33
S x RI x T	.073	2	.037	.72
Error	1.021	20	.051	
R x RI	.054	2	.027	.79
R x RI x T	.351	2	.175	5.10*
Error	.688	20	.034	

Continued ...

Table 1 Continued

Source of Variation	SS	df	MS	F
S x R x RI	.068	2	.034	.87
S x R x RI x T	.015	2	.008	.19
Error	.787	20	.039	
Blocks (B)	.121	1	.121	1.24
B x T	.126	1	.126	1.29
Error	.976	10	.098	
S x B	.149	1	.149	3.48
S x B x T	.015	1	.015	.35
Error	.427	10	.043	
R x B	.058	1	.058	1.72
R x B x T	.037	1	.037	1.11
Error	.336	10	.034	
S x R x B	.271	1	.271	6.74*
S x R x B x T	.162	1	.162	4.03
Error	.403	10	.040	
RI x B	.148	2	.074	1.21
RI x B x T	.112	2	.056	.92
Error	1.220	20	.061	
S x RI x B	.062	2	.031	.95
S x RI x B x T	.009	2	.005	.14
Error	.655	20	.033	
R x RI x B	.068	2	.034	.53
R x RI x B x T	.106	2	.053	.83
Error	1.286	20	.064	
S x R x RI x B	.046	2	.023	1.09
S x R x RI x B x T	.038	2	.019	.90
Error	.421	20	.021	
Total	35.563	287		

*$p < .05$
**$p < .01$
***$p < .001$

Table 1a

Newman-Keuls Comparisons for Reinforcement Symmetry x Retention Interval x Task for Total Number of Transformed Hits

Experimental Condition	Retention Interval 5 s.	10s.	20s.	Difference 5 vs 10	10 vs 20	5 vs 20
i) Within Groups						
DMTS-Asym	63.15	64.14	64.92	.99	.78	1.77
DMTS-Sym	59.18	58.18	58.47	1.00	.29	.71
Asym-Sym Difference:	3.97*	5.96**	6.45**			
DD-Asym	63.45	62.47	60.79	.78	1.88	2.66
DD-Sym	50.85	53.02	52.75	2.17	.27	1.90
Asym-Sym Difference:	12.60**	9.65**	8.04**			
ii) Between Groups						
Asym.						
DMTS vs DD	.30	1.47	3.23			
Sym.						
DMTS vs DD	8.33*	5.16	5.72			

*p < .05

**p < .01

Comparisons	df	p	Critical Values K=2	K=3
Between Groups	60	.05	6.54	7.85
		.01	8.69	9.89
Within Groups	50	.05	3.93	4.73
		.01	5.25	6.01

Table 1b

Newman-Keuls Comparisons for Stimulus x Reinforcement Symmetry x Blocks for Total Number of Transformed Hits

Experimental Condition	Base	Delay	Difference
VS_1 - Asym	94.56	94.68	.12
VS_1 - Sym	84.01	77.67	6.34**
Asy-Sym Difference:	10.55*	17.01**	
AS_1 - Asym	95.31	92.47	2.84
AS_1 - Sym	85.21	86.57	1.36
Asym-Sym Difference:	10.10**	5.90*	

* $p < .05$

** $p < .01$

		Critical Values	
df	P	K=2	K=3
70	.05	4.76	5.72
70	.01	6.32	7.20

observations were supported by significant interactions of Blocks by Retention Interval [F (2,20) = 11.54, $p < .001$], Task by S_1 Modality by Blocks [F (1,10) = 7.77, $p < .05$], Task by S_1 Modality by Retention Interval [F (2,20) = 5.75, $p < .05$], and Task by S_1 Modality by Reinforcement Symmetry by Blocks [F (2,20) = 4.94, $p < .05$]. Individual comparisons based on these interactions revealed that, in general, increases in false alarms were greater at 10 and 20 sec. than 5 sec. RIs ($p < .01$; see Table 2b), and that false alarms increased more to the light than tone S_1 only in the DMTS task ($p < .01$; see Table 2a). The interaction of Task by S_1 Modality by Retention Interval was due to significantly more false alarms to the visual than auditory S_1 at the 10 sec. RI pooled over baseline and retention test blocks in the DMTS task ($p < .05$, Table 2d). Individual comparisons for reinforcement symmetry also revealed that more false alarms occurred to the tone S_1 at the retention test blocks in the asymmetrically than symmetrically reinforced DMTS task.

Results from hits and false alarms data show that differences due to S_1 modality were confined to the DMTS task for increases in false alarms. Greater increases in false alarms from baseline occurred to the light than tone S_1 in the DMTS tasks. Reinforcement symmetry interacted with S_1 modality for hits and with both S_1 modality and task for false alarms. More consistent declines in hits to the light S_1 were found for both symmetrically reinforced tasks, while lower increases in false alarms occurred to the tone S_1 for symmetrical than asymmetrical reinforcement only within the DMTS tasks. These findings suggest that symmetrical reinforcement reduced a bias to lever press to a light S_1 with increased RIs in both types of discrimination tasks, but reduced a bias to press to the tone S_1 only in the DMTS form.

Table 2

Summary of Analysis of Variance of False Alarms for Task, Stimulus, Reinforcement Symmetry, Retention Interval and Blocks

Source of Variation	SS	df	MS	F
Between Ss	9.899	11		
Task (T)	3.897	1	3.897	6.49*
Error	6.002	10	.600	
Within Ss	119.161	276		
Stimulus (S)	.565	1	.565	2.59
S x T	.307	1	.307	1.41
Error	2.181	10	.218	
Reinforcement (R)	.555	1	.555	4.23
R x T	1.155	1	1.155	8.81*
Error	1.311	10	.131	
S x R	.007	1	.007	.05
S x R x T	.488	1	.488	3.22
Error	1.515	10	.152	
Retention Interval (RI)	2.358	2	1.179	12.12***
RI x T	.302	2	.151	1.55
Error	1.945	20	.097	
S x RI	.077	2	.039	1.04
S x RI x T	.430	2	.215	5.75*
Error	.748	20	.037	
R x RI	.095	2	.048	1.06
R x RI x T	.086	2	.043	.96
Error	.897	20	.045	
S x R x RI	.209	2	.105	2.40
S x R x RI x T	.008	2	.004	.09
Error	.870	20	.044	

Continued ...

Table 2 Continued

Source of Variation	SS	df	MS	F
Blocks (B)	81.153	1	81.153	320.23***
B x T	5.746	1	5.746	22.64**
Error	2.534	10	.253	
S x B	.882	1	.882	4.77
S x B x T	1.437	1	1.437	7.77*
Error	1.849	10	.185	
R x B	.012	1	.012	.16
R x B x T	.131	1	.131	1.76
Error	.742	10	.074	
S x R x B	.006	1	.006	.09
S x R x B x T	.339	1	.339	4.94*
Error	.686	10	.069	
RI x B	2.265	2	1.132	11.59***
RI x B x T	.024	2	.012	.12
Error	1.954	20	.098	
S x RI x B	.005	2	.002	.05
S x RI x B x T	.043	2	.022	.44
Error	.971	20	.049	
R x RI x B	.161	2	.081	1.43
R x RI x B x T	.340	2	.170	3.01
Error	1.129	20	.056	
S x R x RI x B	.087	2	.043	2.00
S x R x RI x B x T	.123	2	.061	2.83
Error	.433	20	.022	
Total	129.060	287		

* $p < .05$
** $p < .01$
*** $p < .001$

Table 2a

Newman-Keuls Comparisons of Stimulus x Blocks x Task and Blocks x Task Interactions for Total Number of Transformed False Alarms

i) Stimulus x Blocks x Task

Experimental Condition	Base	Delay	Increase	Difference
DMTS				
VS_1	29.13	86.59	57.46**	18.23**
AS_1	32.66	71.98	39.23**	
Difference	3.53	14.61**		
DD				
VS_1	33.66	60.61	26.95**	2.28
AS_1	31.72	60.95	29.23**	
Difference	1.94	.34		

Between-Group Differences in False Alarm Increases			Comparisons	df	p	Critical Values K=2
DMTS vs DD	VS_1	30.51**	Between Groups	40	.05	9.62
				40	.01	12.84
DMTS vs DD	AS_1	10.00*	Within Groups	30	.05	7.02
				30	.01	9.45

ii) Blocks x Task

Experimental Condition	Base	Delay	Increase	Difference	df	p	Critical Values K=2
DMTS	61.79	158.57	96.78*	30.60**	20	.05	11.91
					20	.01	16.23
DD	65.38	131.56	66.18*				
Difference	3.59	27.01**					

* $p < .05$

** $p < .01$

Table 2b

Newman-Keuls Comparisons for Reinforcement Symmetry x Task and Retention Interval x Blocks Interactions for Total Number of Transformed False Alarms

i) Reinforcement Symmetry x Task

Experimental Condition	Reinforcement			Critical Values		
	Asym	Sym	Difference	df	P	K=2
DMTS	117.90	102.46	15.44**	20	.05	15.13
DD	102.03	94.91	7.12	20	.01	20.62
DMTS-DD Difference:	15.87*	7.55				

ii) Retention Interval x Blocks

	1s	5s	1s	10s	1s	20s	Differences in Increase		
F.A.	42.19	81.73	42.69	96.06	42.29	101.72	5 vs 10	10 vs 20	5 vs 20
Totals Increase	39.54		53.37		59.43		13.83**	6.06	19.89**

Critical Values			
df	p	K=2	K=3
20	.05	7.74	9.35
20	.01	10.42	11.92

* $p < .05$

** $p < .01$

Table 2c

Newman-Keuls Comparisons for Stimulus x Reinforcement Symmetry x Blocks x Task for Total Number of Transformed False Alarms

i) Within Groups

Experimental Condition	Base	Delay	Decline
DMTS			
VS_1 - Asym	16.28	44.14	27.86**
VS_1 - Sym	12.85	42.45	29.60**
Difference	3.43	1.69	
AS_1 - Asym	17.94	39.54	21.60**
AS_1 - Sym	14.72	32.44	17.72**
Difference	3.22	7.10*	
DD			
VS_1 - Asym	17.28	30.82	13.54**
VS_1 - Sym	16.38	29.79	13.41**
Difference	.90	1.03	
AS_1 - Asym	15.71	28.22	12.51**
AS_1 - Sym	16.01	32.73	16.72**
Difference	.30	4.51	

ii) Between Groups Comparisons of False Alarm Increases

VS_1 vs AS_1	VS_1	AS_1	Difference
DMTS - Asym	27.86	21.60	6.26*
DMTS - Sym	29.60	17.72	11.88*
DD - Asym	13.54	12.51	1.03
DD - Sym	13.41	16.72	3.31

table continues

Table 2c continued

DMTS vs DD	DMTS	DD	Difference
Asym VS_1	27.86	13.54	19.94**
Sym VS_1	29.60	13.41	16.19**
Asym AS_1	21.60	12.51	9.09**
Sym AS_1	17.72	16.72	1.00

* $p < .05$

** $p < .01$

			Critical Values	
Comparisons	df	p	K=2	K=3
Between Groups	80	.05	5.51	6.61
	80	.01	7.31	8.33
Within Groups	70	.05	4.72	5.68
	70	.01	6.27	7.15

Table 2d

Newman-Keuls Comparisons for Stimulus x Retention Interval x Task for Total Number of Transformed False Alarms

i) Within Groups	RI					
Experimental Condition	5s	10s	20s	5 vs 10	10 vs 20	5 vs 20
DMTS - VS_1	33.78	41.21	40.76	7.43**	.45	6.98**
DMTS - AS_1	29.54	35.82	39.28	6.28**	3.46	9.74**
Difference:	4.24	5.39*	1.48			
DD - VS_1	28.43	32.33	33.51	3.90	1.18	5.08
DD - AS_1	29.27	32.32	31.00	3.05	1.73	1.32
Difference:	.84	.01	2.51			
ii) Between Groups						
VS_1 DMTS vs DD	5.35	8.88*	7.25*			
AS_1 DMTS vs DD	.27	3.50	8.28*			

* $p < .05$

** $p < .01$

Comparisons	df	p	Critical Values K=2	K=3
Between Groups	60	.05	5.91	7.10
	60	.01	7.85	8.93
Within Groups	50	.05	4.33	5.20
	50	.01	5.75	6.55

P($\bar{A}$) retention scores. Figure 2 shows P($\bar{A}$) scores for each baseline (1 sec. RIs) and each subsequent test block (5, 10, and 20 sec. RIs). P($\bar{A}$) scores for the visual S_1 in the DMTS tasks were generated from hits and false alarms to the L-L and L-T stimulus pairs respectively, and for the auditory S_1 from hits and false alarms to T-T and T-L stimulus pairs respectively. Such scores indicate how well the subject is able to correctly match to either the visual or auditory S_1. P($\bar{A}$) scores in the DD tasks, however, were determined from hits to both L-L and L-T pairs and false alarms to T-T and T-L pairs for the visual S_1, and from hits to the T-T and T-L pairs and false alarms to L-L and L-T pairs for the auditory S_1. Such scores indicate how well subjects can maintain appropriate pressing to the visual or auditory S_1 discrimination tasks.

Inspection of Figure 2 shows that P($\bar{A}$) scores, although declining from baseline at each RI, did so more to the visual than auditory S_1 in DMTS. S_1 modality did not appear to affect this rate of decline in the DD tasks. A significant Task by Modality by Blocks interaction [F (1,10) = 19.67, $p < .01$] and individual comparisons between blocks pooled over RIs ($p < .01$; see Table 3b) supported these observations. Also noteworthy is the finding of greater declines in P($\bar{A}$) only to the visual S_1 in the DMTS than DD task ($p < .01$). Symmetry of reinforcement also affected declines in P($\bar{A}$) as a function of S_1 modality and task. As seen in Figure 2, P($\bar{A}$) declined more to visual S_1 for symmetrically than asymmetrically reinforced DMTS at 5 and 20 sec. RIs. A slightly opposite tendency appeared for the auditory S_1. In the DD tasks, P($\bar{A}$) declined more for symmetrical than asymmetrical reinforcement to both S_1s at 5 and 10sec. RIs and to the visual S_1 at 20 sec. RI. A significant interaction among all five factors [F (2,20) = 4.22, $p < .05$] and

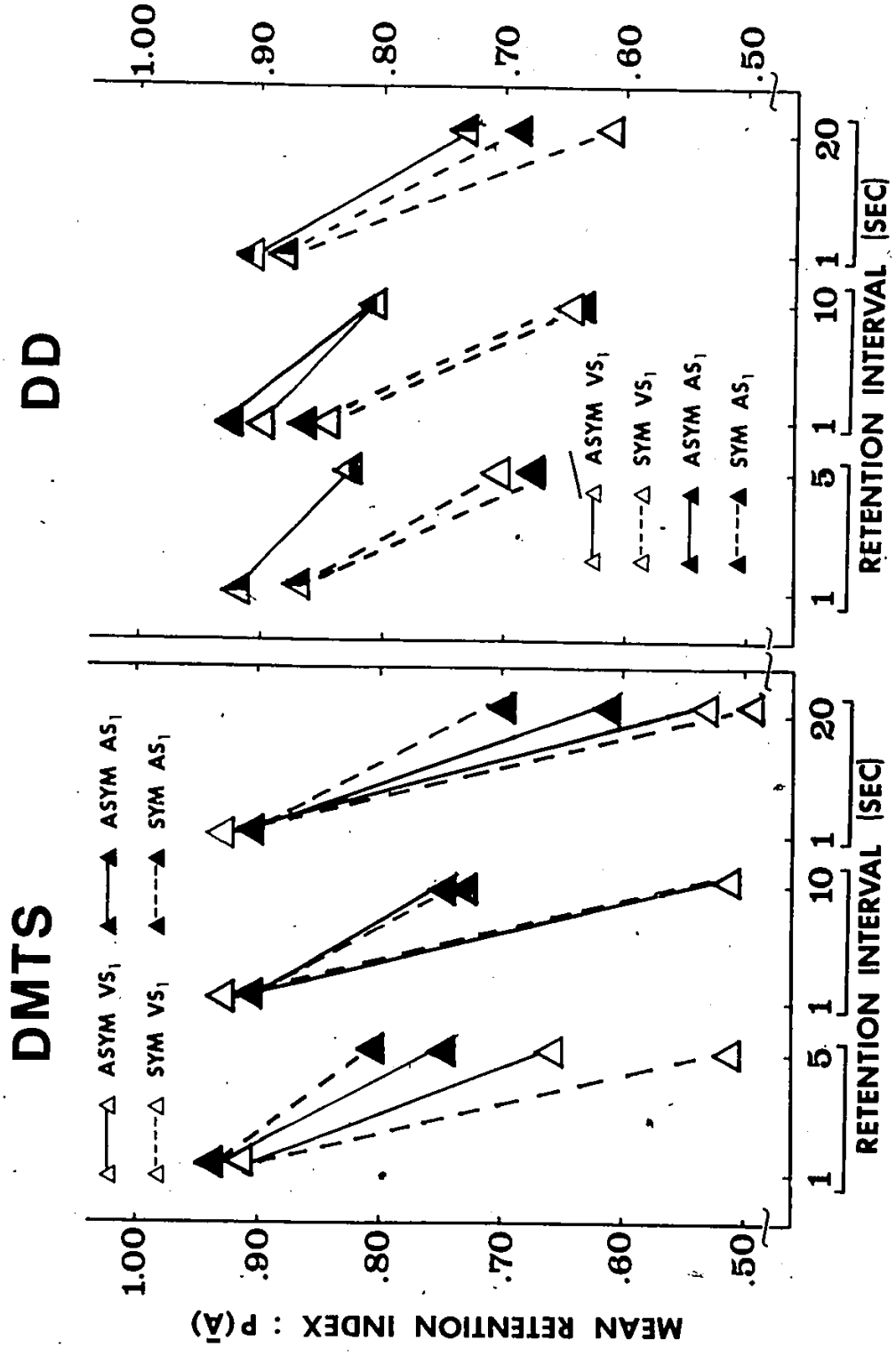
DMTS
DD
ASYM VS1
SYM VS1
ASYM AS1
SYM AS1
1.00
.90
.80
.70
.60
.50
1
5
1
10
1
20
RETENTION INTERVAL (SEC)
MEAN RETENTION INDEX : p(Ā)

FIGURE 2

Table 3

Summary of Analysis of Variance of $P(\bar{A})$ for Task, Stimulus, Reinforcement Symmetry, Retention Interval, and Blocks

Source of Variation	SS	df	MS	F
Between Ss	2.629	11		
Task (T)	.556	1	.556	2.68
Error	2.073	10	.207	
Within Ss	47.926	276		
Stimulus (S)	1.229	1	1.229	38.94***
S x T	.849	1	.849	26.89***
Error	.32	10	.032	
Reinforcement (R)	1.307	1	1.307	15.62**
R x T	.698	1	.698	8.34*
Error	.837	10	.084	
S x R	.173	1	.173	2.76
S x R x T	.151	1	.151	2.41
Error	.627	10	.063	
Retention Interval (RI)	.74	2	.37	8.29**
RI x T	.175	2	.088	1.96
Error	.894	20	.044	
S x RI	.003	2	.002	.03
S x RI x T	.028	2	.014	.22
Error	1.308	20	.065	
R x RI	.006	2	.003	.09
R x RI x T	.128	2	.064	2.00
Error	.641	20	.032	
S x R x RI	.126	2	.062	4.86*
S x R x RI x T	.069	2	.034	2.67
Error	.258	20	.013	

Continued ...

Table 3 Continued

Source of Variation	SS	df	MS	F
Blocks (B)	26.439	1	26.439	408.04***
B x T	1.818	1	1.818	28.05***
Error	0.648	10	.065	
S x B	1.125	1	1.125	19.45**
S x B x T	1.138	1	1.138	19.67**
Error	.578	10	.058	
R x B	.308	1	.308	11.05**
R x B x T	.032	1	.032	1.15
Error	.279	10	.028	
S x R x B	.190	1	.190	6.72*
S x R x B x T	.105	1	.105	3.71
Error	.283	10	.028	
RI x B	.834	2	.417	9.52**
RI x B x T	.024	2	.012	.28
Error	.876	20	.044	
S x RI x B	.045	2	.022	.31
S x RI x B x T	.027	2	.014	.19
Error	1.464	20	.073	
R x RI x B	.014	2	.007	.32
R x RI x B x T	.07	2	.035	1.51
Error	.466	20	.023	
S x R x RI x B	.175	2	.087	5.90*
S x R x RI x B x T	.125	2	.062	4.22*
Error	.296	20	.015	
Total	50.555	287		

*p < .05
**p < .01
***p < .001

Table 3a

Newman-Keuls Comparisons for Blocks x Task and Reinforcement Symmetry x Blocks x Task Interactions for Transformed $P(\bar{A})$

i) Blocks x Task

Experimental Condition	Base	Delay	Decline	Difference	Critical Values df	p	K=2
DMTS	185.61	130.54	55.07**	23.56**	20	.05	9.23
					20	.01	12.51
DD	180.06	148.31	31.75**				
Difference:	5.55	17.77**					

ii) Reinforcement Symmetry x Blocks x Task

Experimental Condition	Base	Delay	Decline	Difference
DMTS-Asym	92.66	66.72	25.94**	1.31
Sym	92.95	68.32	24.63**	
Difference:	.29	1.60		
DD-Asym	92.89	79.91	12.98**	6.23**
Sym	87.61	68.40	19.21**	
Difference:	5.28**	11.51**		

Between Groups	Base	Delay	Comparisons	df	Critical Values p	K=2	K=3
DMTS vs DD: Asym	.23	13.18**	Between Groups	40	.05	5.32	6.40
				40	.01	7.10	8.13
DMTS vs DD: Sym	5.34	.08	Within Groups	30	.05	3.64	4.36
				30	.01	4.90	5.61

* $p < .05$

** $p < .01$

Table 3b

Newman-Keuls Comparisons of Stimulus x Blocks x Task for Transformed $P(\overline{A})$

Experimental Condition	Base	Delay	Decline	Difference
i) Within Groups				
DMTS VS_1	93.01	56.45	36.56**	18.05**
AS_1	92.60	74.09	18.51**	
Difference:	.41	17.64**		
DD VS_1	89.84	73.77	16.07**	.05
AS_1	90.66	74.54	16.12**	
Difference:	.82	.77		
ii) Between Groups	Base	Delay	Decline	Difference
DMTS vs DD: VS_1	3.97	17.32**	20.49**	
DMTS vs DD: AS_1	1.94	.45	2.39	

* $p < .05$

** $p < .01$

	Critical Values		
Comparison	df	p	K=2
Between Groups	40	.05	5.16
	40	.01	6.90
Within Groups	30	.05	3.37
	30	.01	4.51

Table 3c

Newman-Keuls Comparisons for Retention Interval x Blocks and Stimulus x Reinforcement Symmetry x Retention Interval Interactions for Transformed $P(\bar{A})$

i) Retention Interval x Blocks

RI:	5s			10s			20s		
Base	5s	Decline	Base	10s	Decline	Base	20s	Decline
124.05	99.02	25.03**	122.08	93.08	28.28**	122.50	86.77	35.73**

Comparison	5s vs 10s	10s vs 20s	5s vs 20s
Baseline Differences	1.98	.42	1.55
Delay Differences	5.94**	6.31**	12.25**
Decline Differences	3.25	7.45**	10.70**

Critical Values (RI x B)

df	p	K=2	K=3
50	.05	4.36	5.24
50	.01	5.82	6.66

ii) Stimulus x Reinforcement Symmetry x Retention Interval

Experimental Condition	5s	10s	20s	5 vs 10	10 vs 20	5 vs 20
Asym - VS_1	55.82	53.92	53.41	1.90	.51	2.41
Asym - AS_1	57.83	56.88	54.32	.95	2.56	3.51
Difference:	2.01	2.96	.91			
Sym - VS_1	51.60	50.42	47.90	1.18	2.52	3.70
Sym - AS_1	55.92	53.32	53.64	2.60	.32	2.28
Difference:	4.32*	2.90	5.74*			
Asym vs Sym:						
VS_1	4.22**	3.50**	5.51**			
AS_1	1.91	3.56**	.68			

Critical Values

df	p	K=2	K=3
110	.05	3.06	3.68
110	.01	4.07	4.63

* $p < .05$
** $p < .01$

Table 3d

Newman-Keuls Comparisons for Stimulus x Reinforcement Symmetry x Blocks for Transformed $P(\overline{A})$

Experimental Condition	Base	Delay	Decline	Difference
Asym VS_1	92.63	70.52	22.11**	5.30**
AS_1	92.92	76.11	16.81**	
Difference:	.29	5.59**		
Sym VS_1	90.22	59.70	30.52**	12.70**
AS_1	90.34	72.52	17.82**	
Difference	.12	12.82**		
Asym vs Sym				
VS_1	2.41	10.82**		
AS_1	2.58	3.59		

Critical Values		
df	p	K=2
70	.05	3.84
70	.01	5.10

* $p < .05$

** $p < .01$

individual comparisons ($p < .05$; see Table 3e) supported most of these observations. Only the observed greater declines in $P(\overline{A})$ in the asymmetrically than symmetrically reinforced DMTS to the tone S_1 failed to reach significance. Further examination of the individual comparisons revealed that increased RIs resulted in greater declines in $P(\overline{A})$ more consistently to the visual than auditory S_1. Greater declines occurred to the visual S_1 at 20 than 5 sec. RIs for each task and condition of reinforcement symmetry ($p < .05$). A similar effect to tone S_1 only occurred in the asymmetrically reinforced form of either task ($p < .05$).

Table 3e

Newman-Keuls Comparisons for Stimulus x Reinforcement Symmetry x Retention Interval x Blocks x Task for Transformed $P(\bar{A})$

Experimental Condition		1s	5s	Decline	1s	10s	Decline	1s	20s	Decline
DMTS -	Asym-VS_1	15.17	11.29	3.88**	15.69	9.53	6.16**	15.62	9.79	5.83**
	AS_1	15.65	12.71	2.94**	15.25	12.57	2.68**	15.28	10.83	4.45**
	Difference:	.48	1.42*	.94	.44	3.04**	3.48**	.34	1.04	1.38*
DMTS -	Sym-VS_1	15.64	9.46	6.18**	15.42	9.60	5.82**	15.47	6.78	8.69**
	AS_1	15.86	13.79	2.07**	15.34	12.30	3.04**	15.22	11.89	3.33**
	Difference:	.22	4.33**	4.11**	.08	2.70**	2.78**	.25	5.11**	5.36**
DD -	Asym-VS_1	15.43	13.93	1.50**	15.19	13.51	1.68*	15.53	12.47	3.06**
	AS_1	15.33	14.14	1.19	15.68	13.38	2.30**	15.73	12.48	3.25**
	Difference:	.10	.21	.31	.49	.13	.62	.20	.01	.19
DD -	Sym-VS_1	14.52	11.98	2.54**	14.28	11.12	3.16**	14.89	10.76	4.13**
	AS_1	14.55	11.72	2.83**	14.61	11.05	3.56**	14.76	11.77	2.99**
	Difference:	.03	.26	.29	.33	.07	.40	.13	1.01	1.14

table 3e continues

Table 3e continued

Asym vs Sym (Delay sessions only)

	Delay:	5s			10s			20s	
	Asym.	Sym.	Diff.	Asym.	Sym.	Diff.	Asym.	Sym.	Diff.
DMTS -VS_1	11.29	9.46	1.83**	9.53	9.60	.27	9.79	6.78	3.01*
AS_1	12.71	13.79	1.08	12.57	12.30	.27	10.83	11.89	1.06
DD -VS_1	13.93	11.98	1.95**	13.51	11.12	2.39**	12.47	10.76	1.71*
AS_1	14.14	11.72	2.42**	13.38	11.05	2.33**	12.48	11.77	.71

ii) Between Groups Differences

DMTS vs DD	1s	5s	1s	10s	1s	20s
VS_1 - Asym.	.26	2.64**	.50	3.98**	.09	2.68**
Sym.	1.12	2.52**	1.14	1.52*	.58	3.98**
AS_1 - Asym.	.32	1.43	.43	.81	.45	1.65
Sym.	1.31	2.07**	.73	1.25	.46	.12

* $p < .05$

** $p < .01$

			Critical Values	
Comparisons	df	p	K=2	K=3
Between Groups	240	.05	1.50	1.79
	240	.01	1.97	2.22
Within Groups	230	.05	1.36	1.62
	230	.01	1.78	2.02

CHAPTER IV

DISCUSSION

The hypotheses concerning reinforcement symmetry and stimulus modality both received some support. The prediction for reinforcement symmetry, that symmetrical reinforcement would yield more accurate responding than would asymmetrical reinforcement in DMTS with the opposite pattern predicted for $\overline{DD}$, was only partially validated. Asymmetrical reinforcement consistently produced more accurate responding to S_1 than did symmetrical reinforcement in the DD task. Apparently, the inclusion of the more complicated symmetrical payoff matrix attenuated the accuracy of performance of animals in the DD with increased RIs. However, the predicted pattern of findings for reinforcement symmetry in DMTS did not occur. There was no overall effect of reinforcement symmetry on $P(\bar{A})$ as a measure of accuracy of responding in DMTS. Where significant differences did occur, they were in the opposite direction to that predicted, such that asymmetrical reward produced lower declines in $P(\bar{A})$ than did symmetrical reinforcement to the visual S_1 in DMTS. Consequently, the present study failed to corroborate previous findings in rats (Cohen et al., 1984) of superior performance in DMTS being associated with a symmetrical rather than an asymmetrical payoff matrix to the auditory S_1. Given that the same species of rat, the same task, and the same equipment was used here as in Cohen et al.'s investigation, it appears that the effect of reinforcement symmetry on response accuracy in DMTS is not reliable.

However, reinforcement symmetry did have a strong effect in delayed discrimination . As mentioned previously, greater declines in accuracy of

responding in this task occurred for symmetrical than asymmetrical reinforcement. This effect is consistent with Honig and Wasserman's (1981) notion that animals use prospective instructional sets in delayed discrimination rather than in delayed real or symbolic matching-to-sample tasks. Under symmetrical reinforcement, different types of responding will produce the same reinforcement, pressing for some stimulus pairs, omission of pressing for others. Under asymmetrical reinforcement only pressing to same stimulus pairs will produce reinforcement. The rule for responding in a symmetrically reinforced task is more complex by virtue of containing more elements of information than that for asymmetrical reinforcement. Therefore, an animal should have more difficulty in retaining or covertly rehearsing the rule in a symmetrically than asymmetrically reinforced task. Since reinforcement symmetry affected delayed responding in the simple rather than in the conditional (matching-to-sample) delayed discrimination, prospective retention of response-reward instructions was more likely to be used only in the former.

With respect to stimulus modality, the hypothesis relevant to this factor, that subjects would show less accurate responding to a visual S_1 than to an auditory S_1 in DMTS with no effect of modality expected for DD, was fully supported. This finding could be interpreted as indicating the operation of retrospective memory processing in DMTS and prospective processing in DD. As animals in the DD responded with comparable levels of accuracy to both a visual S_1 and an auditory S_1, it appears that they were utilizing a prospective rule (i.e., "press" or "don't press") during the retention interval rather than maintaining a representation of S_1.

In contrast, the greater accuracy of responding to an auditory than to a visual S_1 in DMTS, both in terms of overall level of retention and

decline in retention from baseline to delay, suggests that the animals maintained a representation of S_1 during the retention interval, and hence, that DMTS elicited a memory strategy that is at least in part a retrospective process. If the animals were not retrospecting the nature of the initial stimulus during the retention interval, then S_1 should merely have instructed the subject as to which S_2 required a press for reinforcement and the modality of S_1 should not have affected these instructions.

The obtained stimulus modality effect, then, is very conducive to a retrospective-prospective interpretation, and seems to confirm Honig and Thompson's (1982) model of working memory. Nevertheless, other explanations should be considered. First, one could argue that the obtained modality effect is not related to the rats' memory for visual and auditory stimuli but rather shows that the animals have greater difficulty perceiving visual than auditory stimuli and/or greater difficulty forming associations to visual than auditory stimuli. However, these rival hypotheses have been ruled out by previous research in the same lab which showed light to be a more salient stimulus than tone for Wistar rats in an operant discrimination task (Cohen, Mehan, & Shpuniarsky, 1984). A second alternative explanation is not as easy to disqualify and is similar to a prospective account offered by Honig and Wasserman (1981) for their findings with pigeons. It may be that the differential accuracy of responding to the visual and auditory S_1 in DMTS reflects not a difference in retrospective memory for visual and auditory stimuli but a difference in memory for visual and auditory stimulus-contingent prospective rules. Rather than maintaining a retrospective representation of S_1 during the retention interval, the subject may in fact be remembering a prospective response rule (e.g., "respond if the test stimulus is light, do not respond if the test

stimulus is tone"). If this were the case, the S_1 modality effect could be explained in the following fashion: It may be easier to remember a prospective rule with a tone stimulus component (i.e., for tone-tone matching trials) than to remember a response rule with a light stimulus component (i.e., for light-light matching trials), and, as a result, matching to a visual S_1 is less accurate than matching to an auditory S_1. This hypothesis could also account for the lack of modality effects in DD. As S_2 is not relevant to the determination of a trial outcome in DD, the prospective rules for this task do not require a test stimulus component and consequently, no stimulus modality effects occur in this experimental procedure.

One way to test this hypothesis is to compare a delayed matching (DMTS) to a delayed mismatching to sample (DMMTS) task. In the latter, reinforcement would be contingent upon pressing on L-T and T-L pairs, but pressing on L-L and T-T pairs would be nonreinforced. According to the S_2 prospective hypothesis, accuracy of responding should be poorer for pairs of stimuli containing visual than auditory S_2 but modality of S_1 should have no effect. To date, we have run six animals on an asymmetrically reinforced delayed mismatching to sample at a 5 sec. RI following baseline. Five out of six animals showed better mismatching to sample to the auditory than visual S_1. These preliminary findings go against the S_2 prospective hypothesis and confirm the S_1 retrospective hypothesis.

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